Division of Agricultural Sciences
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Gum Diseases of Citrus

IN CALIFORNIA

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California Citrus Orchards

are attacked by a number of diseases in which the formation of gum on the trunks or branches is a conspicuous symptom. These diseases are grouped under the general classification of gummosis, but their outward appearances and ultimate effects on the trees differ, to some extent.

The cause of some forms of gummosis is not known.

For most forms, effective methods of treatment are known.

In most cases, protective measures can be taken to guard against the danger of infection.

The basic preventive measures include:

1. Keeping excess moisture from contact with trunks and crowns for extended periods.
2. Keeping manure and other organic matter away from the bases of the trees.
3. Spraying or fumigating only when conditions are favorable.
4. Making periodical inspections of the trees to spot infection before too much damage is done.

This Circular

is designed to help growers recognize the various types of gummosis and to prevent or combat them.

Many of the points discussed here have been touched on in other publications listed on page 22. But the material included here is, as far as known, the latest information available.

The material on Phytophthora gummosis in the former edition referred only to the effects of *P. citrophthora*, the species commonly causing brown rot of fruit and gummosis of bark. The coming into use of other rootstocks such as mandarins and citranges has brought to light the increasing importance of other species of Phytophthora, particularly *P. parasitica*.

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Gum Diseases of Citrus

IN CALIFORNIA

Any gum disease in a citrus orchard is important when it threatens the useful life of the trees. The greatest amount of space in this circular has been devoted to brown rot gummosis because it is the most destructive of the gum diseases, and because considerable is known about its cause and treatment—not because the other gum diseases are felt to be unimportant.

With this in mind, the various gum diseases are here discussed one at a time, together with their causes, symptoms, prevention, and known treatments.

Brown Rot Gummosis

or Foot Rot

Since both brown rot gummosis and foot rot are caused by the same fungi and require the same preventive and curative treatments, they are now considered to be different forms of the same disease. They are discussed together here.

During the wet years of 1938, 1941 and 1943 it is estimated that 900,000 cases of this disease developed in California citrus orchards. The disease is fatal to trees if they are allowed to go untreated.

THE CAUSE of brown rot gummosis and/or foot rot is infection of the tree by one or more species of the *Phytophthora* fungi. These fungi attack the trees in different places, above and below ground, and bring about several types of injury.

The several species of brown rot fungi can attack leaves, blossoms, and fruit; one species being particularly destructive to fruit and foliage because its spore cases become detached and distributed throughout the tree by wind and wind-driven rain. Two species invade and destroy the bark of the trunk and rootstock. The infection may girdle the tree and eventually kill it.

The indirect cause of these diseases may be one or more conditions in the orchard that favor growth and multiplication of the fungi. These conditions are:

1. Having water in contact with the trunk and crown for as short a time as 5 hours. This may be due to flooding with irrigation water, or to heavy soils which do not drain readily.
2. Injuries to lower trunk made by cultivation tools.
3. Temperatures near the optimum for the growth of the fungi; 78°F for *P. citrophthora* and 89°F for *P. parasitica*, the two most important species causing gummosis.
4. Manure and other organic material piled against the trunk.

Obviously, these cultural practices should be avoided.

THE SYMPTOMS of brown rot gummosis are varied, depending on where the tree is attacked.

In established trees the first and most evident symptom seen is a profuse gumming on the surface of the affected bark. From infections originating below ground in the so-called foot rot form, this gum is absorbed by the soil. The infection soon extends above ground, however, producing the typical masses of gum which exude and may harden in long, vertical ridges on the surface of the bark,

or run down onto the soil, as in the photograph at left.

Brown rot gummosis can usually be distinguished from other forms of fungus infections by the severity of the gumming and by the fact that the affected bark is firm and will not yield to pressure by the fingers. Above ground this bark, even though it is killed entirely through to the wood, will remain firm until it is dried out and cracked in vertical, flint-like strips infiltrated with hardened gum.

When scraped, the affected parts appear darker than the surrounding green tissue. Removal of the bark will reveal a dark brown staining on the cambial surface (soft, formative tissue between the bark and wood). Usually, but not always, this dark color marks the boundaries of the infection. Sometimes the infection in the outer bark will have extended beyond the boundaries of the discoloration on the cambial surface.

Beyond the region in the bark actually invaded by the fungus is a chamois-colored zone on the cambial surface in which a clear, watery gum is sometimes apparent. Since the causal fungus is not present in this zone, it should not be treated, even though it extends several times the length of the invaded (dark stained) zone.

Below ground, if the soil is moist, secondary organisms may cause a soft, malodorous decay of the bark, and a staining of the wood.

Twig injury, decay of fruit, blossoms and leaves during, or immediately following rainy, windy weather are also symptoms of infection by *Phytophthora* fungi. As stated, *P. citrophthora*, does its greatest damage at temperatures near 78°F and *P. parasitica* near 89°F. Two

Here is a typical example of brown rot gummosis on a lemon trunk, before and after surgical treatment. This treatment is described on page 7 and consists of cutting out diseased bark and disinfecting the area in which fungi are present.

other species, *P. hibernalis* and *P. syringae* are known to attack citrus in California. Their optimum temperature for growth being near 63°F, they are active below ground and during cool weather.

In nursery trees and young orchard trees the symptoms of brown rot gummosis are usually discovered by examining the crowns, and are characterized by gumming, staining of the bark and wood, as described above for old orchard trees.

COMBATIVE MEASURES include both prevention (or avoidance) and curative treatments, for both old and new plantings. Preventing the disease in established plantings consists in avoiding the orchard conditions, listed above, that favor growth of the fungi.

Prevention in new plantings, or in replacement plantings may start with choice of a stock that has been shown to be relatively resistant to the disease and not susceptible to other fatal diseases such as quick decline.

The point is, that while resistance to gummosis is important in selection of a stock, it is not the *only* consideration. For instance: sweet orange on sour orange stock is highly resistant to gummosis, but very susceptible to quick decline (tristeza).

Other stocks that are relatively resistant to gummosis may not be suitable from a cultural standpoint, due to the climate in a given locality.

It is therefore recommended that stock be chosen for its suitability from a cultural standpoint as a prime consideration, and that its susceptibility to gummosis be considered secondarily (5).* Even though a stock is very susceptible to gummosis, by using the precautions recommended in this circular, it can be successfully protected against the disease.

Work at the experiment station has resulted in a tabulation of citrus tree stocks, arranged according to their mean resistance as groups to brown rot gummosis. The table is shown below.

Because of the excellent bud union (when grafted) and rapid growth made by commercial varieties of citrus on sweet orange rootstock, and the desirability of

* Numbers in parentheses refer to literature citations on page 22.

Lemons (*Citrus limon*) Citranges (Trifoliate × Sweet) except Troyer citrange	Highly susceptible
Limes, (*C. aurantifolia*) Grapefruit (*C. paradisi*) Rough lemons (*C. limon*) (hybrid) Most selections of trifoliate orange (*Poncirus trifoliata*) Sweet oranges (*C. sinensis*) Mandarins (*C. reticulata*) Troyer citrange Tangelo, Sampson (tangerine × pummelo) (Susceptible to *P. parasitica*)	Less susceptible
Sour oranges (*C. aurantium*) Some selections of trifoliate orange Kumquat (Marumi and Nagami) *Fortunella* sp.	Resistant

avoiding quick decline (a disease common to sweet orange varieties on sour orange stock), many growers are demanding sweet orange rootstocks for new and replacement plantings.

The following procedure is therefore recommended for those who wish to make new or replacement plantings of the less resistant rootstocks. In fact, this procedure is recommended for *all* new and replacement plantings, regardless of the stock used.

The first step is examination of the crown. (For symptoms, see page 5.)

With trees that come from a nursery balled in burlap, a representative sample (normally from 5 to 10 per cent of all of the trees) should be carefully examined by exposing the crown. All trees showing evidence of infection should, of course, be rejected. If more than 10 per cent of the trees examined show evidence of infection, the entire lot should be rejected. In any case, however, it would be well to have an understanding with the nurseryman from whom the trees are purchased regarding replacement of trees that develop brown rot gummosis within 6 months after planting.

Before planting, young trees should be treated for protection against brown rot gummosis.

Balled trees should have the balls dusted with a one-package, spray-dried bordeaux dust, or with a one-package, spray-dried zinc sulfate-copper sulfate-hydrated lime dust. Or if it is more convenient, the balls may be sprayed thoroughly with a 3-3-100 bordeaux* mixture. The only choice between these protective measures is one of convenience for the grower.

Bare root trees may be cleaned of infection by the common brown rot fungus, *P. citrophthora* before planting by immersion in hot water, because the citrus nursery trees will tolerate higher temperatures than this gummosis fungus.

To do this, a way must be provided to keep the water at a fairly constant temperature and keep it circulating throughout the entire operation. The rootstocks and the entire root systems may then be immersed in the water for any one temperature and corresponding time period as follows:

Temperature of water	Time of immersion
110° F	10 minutes
111° F	8 "
112° F	6 "

The temperature-time exposures shown will serve to kill *P. citrophthora.* One-year-old seedlings of Cleopatra mandarin, Sampson tangelo, Jochimsen grapefruit, Rough lemon, Jameson sweet orange, standard sour orange, Rubidoux and Webber-Fawcett trifoliate orange, Troyer citrange, and Ichang pummelo heeled into soil for 2 weeks before treatment tolerated an immersion of their roots in water at 118° F for 10 minutes without any apparent injury. Because of the importance of injury to roots by the citrus nematode, *Tylenchulus semipenetrans,* it should be mentioned here that while 118° F for 10 minutes will destroy this parasite, it will survive the above-tabulated exposures (1). Birchfield (3) in Florida found 122° F for 10 minutes necessary to kill the burrowing nematode, *Radopholus similis.* Unfortunately, this exposure would be very injurious to nursery trees or seedlings of some varieties and would also be ineffective against the thick-walled oöspores of *P. parasitica.*

Planting. It has been found by inoculation that the bark of the root of the stem portion and other large roots of the stock is several times more resistant to gummosis disease than that of the stem of

* 3-3-100 bordeaux mixture contains 3 pounds of blue vitriol or copper sulfate ($CuSO_4 \cdot 5H_2O$) and 3 pounds of hydrated lime [$Ca(OH)_2$] in 100 gallons of water. Because of the danger of copper injury, a good quality and adequate amount of hydrated lime should be used in making homemade bordeaux.

the stock. It is therefore well to plant the trees high, so that the first side roots are just barely under the soil surface and the bud union 6 inches or more above ground level.

Just before the first irrigation, dust the trunk to a height of one foot with bordeaux or zinc-copper-lime dust, or whitewash with the same materials stirred into enough water to make a suspension about the consistency of house paint.

If the dust is used, the treatment should be repeated every four months during the first year. Two applications of the liquid are sufficient.

Where conditions for infection are prevalent, the protective treatment should be continued through the second year, or until the trees have made sufficient growth that irrigation water may be kept away from the trunk.

Inspection. Trees in any orchard, old or new, should be examined at least once a year. Remove the soil around the crown and down to the first lateral roots if infection above ground is evident. Care should be taken to make sure that no depressions are left, during this procedure, into which water is likely to drain and stand. If it is necessary to leave a depression, a drainage outlet should be dug.

By following the above practice, it is possible to detect gummosis and other troubles in the early stages so that corrective measures can be taken.

Treatment. When gummosis is discovered in the crown or trunk of established trees, the diseased bark should be removed by cutting it away to a line extending ¼ to ½ inch into the surrounding healthy bark (see photo, page 5). The margin of the diseased area may be located roughly by the origin of the gumming, and then more definitely by a light scraping with a knife or tree scraper.

The infected part, when scraped, appears darker than the surrounding green tissue. The inner, or cambial surface, of the diseased bark and wood is a dark reddish brown. The tan, or chamois-colored, bark beyond is not invaded by fungus and should not be removed or disturbed.

It is not necessary to scrape or cut the wood. By scraping the bark lightly to a line 1 to 2 inches beyond the area of invasion, the tendency to gum following the painting with bordeaux is decreased.

The exposed wood should be disinfected with either a 1 per cent solution of potassium permanganate (1 teaspoonful of crystals to a pint of water) or with a paint made by mixing the powder of fresh one-package, spray-dried bordeaux with water to about the consistency of house paint. The choice between these two treatments depends on whether or not fumigation is contemplated. If fumigation is to follow, the potassium permanganate treatment should be used because there is a danger that the copper in bordeaux will react with the hydrocyanic gas and injure the trees.

After application of the above treatment, when healing calluses begin to show at the edges of the bark, the wood should be painted with white lead or with a noninjurious asphalt emulsion.

If the diseased area is larger than a man's hand, or of long standing, a 2- to 3-inch strip may be removed from the margin toward the center of the affected bark, and the dead, dry center portion, which is difficult to remove, may be left because the causal fungus is killed out by the drying. It is not advisable to attempt to treat a small tree that has a gummosis lesion involving half or more of the circumference. It is better to replace it.

Twig invasions. As stated above, the fungi that cause brown rot gummosis sometimes invade the upper parts of the trees, causing twig injury and/or decay of fruit, blossoms and leaves. This type of infection may be prevented, but not cured.

The most effective known method of prevention is to spray 1 to 3 weeks prior to, or just after, the first rain of the season with a 3-4½-100 bordeaux mixture, or a 5-2-6 zinc-copper-lime mixture, or a reacted and spray-dried copper fungicide

containing 0.6 to 0.8 pounds of copper (metallic) per 100 gallons.*

In some localities the application of copper sprays has aggravated leaf fall and caused pitting of leaves and fruit. For these reasons, and because copper sprays also aggravate HCN fumigation injury, concentrations of bordeaux and other copper sprays have been reduced to these dilute sprays, and sprays of non-copper materials sought as substitutes.† One of the more promising is Captan used at the rate of 2 pounds of the chemical (50 per cent active ingredient) per 100 gallons of water. Since this does not resist weathering as well as the copper sprays a second application should be made 10 to 12 weeks after the first (8, 23).

Where there is no history of infection above the 4-foot level, spray the foliage and fruit to that height. Also spray the ground under the tree and the trunk.

Where injury has appeared in previous years above the 4-foot level, indicating that the aerial form of the fungus is present, or if correction of copper or zinc deficiency is desired, the entire tree and the ground under the tree should be thoroughly sprayed.

Gummosis

Caused by Other Fungi

Several other types of gummosis caused by fungi have been found in California and while they are not as important commercially as brown rot gummosis, it is advisable to know their symptoms and to guard against them.

Prevention and treatment methods are essentially the same for all of these diseases. However, some of the causal fungi occasionally invade both wood and bark, necessitating their removal by surgery, and disinfection and covering of the exposed healthy wood.

THE DIRECT CAUSE of these other types of gummosis is, of course, infection by fungi. The indirect cause may often be:

1. Damage to the trees by frost, sunburn, mechanical injury, oil sprays, fumigation, or the various chemicals used in sprays and fertilizers.
2. Weakening of the trees' natural resistance by infections of shell bark and virus. (See pages 17 and 19.)

THE GENERAL SYMPTOMS of infection by these minor forms of fungi are similar to those of brown rot gummosis, but the gumming is usually less profuse, and the extent and severity of the damage is usually less.

Invasion of bark by *Botrytis cinerea* (gray mold) is detected by the presence of the gray-colored, velvety, fruiting heads of the fungus on the bark surface (see photo). In the early, active stage, the bark is soft.

This disease may cause considerable damage to trees injured by cold or by shell bark.

* Bordeaux mixture 3-4½-100 contains 3 pounds of powdered copper sulfate (pentahydrate) called bluestone; 4½ pounds of hydrated lime; in 100 gallons of water. Zinc-copper-lime, 5-2-6-100 contains 5 pounds of zinc sulfate (heptahydrate); 2 pounds of powdered bluestone; and 6 pounds of hydrated lime in 100 gallons of water. Zinc sulfate monohydrate may be used; 3 pounds are equivalent in zinc to 5 pounds of the heptahydrate.

† For areas where damage from copper sprays is severe (areas with air pollution, smog, sulfur oxides) either the zinc-copper-lime 5-2-6-100 or Captan 50W, 2 pounds in 100 gallons or equivalent in active ingredient, may be used (8, 23). Captan residue on fruit must not exceed 100 ppm of the whole fruit. Do not feed citrus by-products, that have been treated with captan, to dairy animals or animals being finished for slaughter.

Here branches and twigs of a lemon tree have been invaded by Botrytis fungus, following injury by freezing. Both preventive and curative measures may be taken to combat this type of disease.

The cottony rot fungus, *Sclerotinia sclerotiorum*, may attack and kill all parts of the tree that have been injured. As in Botrytis gummosis, the affected bark is soft at first, but turns gray to almost white and breaks up into shreds. Among the shreds of bark on the wood surface are black, irregular bodies of the resting stage of the fungus. Gumming may be rather profuse, but not as profuse as in brown rot gummosis.

Both *Botrytis* and *Sclerotinia* fungi cause twig blights that are similar in nature. Starting in the ends of twigs or in the blossoms they kill the twigs back for a few inches. Their progress is arrested, however, by warm, dry weather.

Diaporthe citri and *Diplodia spp.* attack bark weakened by shell bark disease (see page 17) and by other factors mentioned above, causing a gummosis. They and *Botrytis* will also invade growth cracks, pressure ridges and wounds. These fungi are particularly severe when working together in shell bark areas, for they may kill the bark through to the cambium, and the *Diplodia* may invade the wood. *Diplodia* advances in the wood of twigs and limbs injured by frost. Either *Diaporthe citri* or *Diplodia spp.* alone is able to invade the inner bark, and the former (Phomopsis stage), although usually confined to bark, can invade the wood of weak trees. On the affected parts the black spore-containing structures (tiny black spheres embedded in the bark) of the two fungi may be found.

Two bark diseases, Diplodia gummosis and Dothiorella gummosis (caused by the Dothiorella stage of *Botryosphaeria ribis*) are so much alike that it is difficult to distinguish one from the other. They attack the trunk, large limbs and crotch of trees that have been weakened by cold, age, or other agencies, and may destroy large areas of bark and kill large limbs or the entire tree. They may also attack the wood. However, the lesions are often small and easily healed.

They are characterized by the forma-

tion of elongated gum pockets in the inner bark, next to the wood surface. The affected inner bark is brown to black in color.

COMBATIVE MEASURES. Keeping the danger from these fungus diseases at a minimum is very important, and may usually be accomplished by taking the following steps:

1. Avoid injury to the trees by cultivation tools and burrowing animals.
2. Where possible, provide adequate orchard heating to prevent weakening of the trees by cold.
3. When frost damage does occur, protect the exposed bark by whitewashing.
4. Disinfect pruning cuts with mercuric chloride or mercuric cyanide (2-1,000 in a 25 per cent solution of denatured alcohol in water), or 4 per cent formalin, or a safe carbolineum. Allow disinfectant to dry for 3 days, then cover with a white lead paint, an asphalt paint or a tree seal.
5. Do not fumigate when the soil or trees are wet, or when the temperature is above 70° F.
6. Avoid applying oil sprays when the trees are too dry.
7. Distribute fertilizer evenly over ground surface so it does not pile against trees.

In addition, painting or spraying the trunks and crotches of the trees with fungicides such as bordeaux, or zinc-copper-lime mixture (about the consistency of house paint), or with one of the new carbamate fungicides (½ per cent solution) will discourage some of the fungi.

Surgical treatment for any of the above fungus diseases is the same.

The invaded parts are cut away to a line ¼ to ½ inch beyond the margin of the lesions and the surface is painted with bordeaux paste or with a noninjurious brand of carbolineum (i.e. carbolineum having a relatively low phenol content). Any carbolineum or asphalt paint should be tried out on small areas of bark in the sun and shade. If it roughens or kills the bark, it has too high a content of phenol.

Where the fungi have killed only the outer layers of bark, the bark should be removed by scraping with a tree scraper. Wood invaded by *Diplodia* or *Dothiorella* should be removed and the cut surfaces disinfected with mercuric cyanide or mercuric chloride (2 parts in 1,000 parts of 25 per cent alcohol) or with bordeaux paste. When the wounds are dry, either of these treatments should be followed by covering with a noninjurious asphalt paint.

A single application of a safe carbolineum, without a follow-up coat of asphalt paint, may also be used, but the exposed bark and wood should be whitewashed to prevent sunburning.

Dry Root Rot

Resembles Brown Rot

Dry root rot is occasionally found in conjunction with or confused with old cases of brown rot gummosis, but familiarity with the special symptoms of dry root rot will enable a grower to recognize one from the other in most cases.

THE EXACT CAUSE of dry root rot is not known. The disease has been found in conjunction with injuries due to such agencies as kerosene sprays, gophers, concentrated fertilizers, and fumigation chemicals. It has also been found in

Photo at left shows root system of a citrus tree infected with dry root rot. Photo on the right shows cross sections of a citrus rootstock with the typical staining of the wood that accompanies dry root rot. (Photo at left courtesy of J. T. Barrett.)

places where it was possible to eliminate all of these factors.

Generally it is possible to relate the disease to unfavorable conditions of excess moisture and poor aeration.

SYMPTOMS. The disease is usually confined to the rootstock and the main roots near the crown of the tree, and is characterized by a moist decay of the bark, in the early stages, and a dry condition of the bark with hard, dead wood underneath, in the later stages (see photo, above). The affected parts frequently have a fishy odor.

The areas involved may be small and self-limited, with new bark eventually forming over them—or they may be extensive, involving many of the main roots and rootlets. The disease is nearly always fatal if the crown of the tree is involved.

The appearance of the tree above ground depends on the number of roots affected. Leaves may wilt suddenly and dry up in place, as in the collapse stage of the decline diseases. Or some of the leaves may drop, giving the tree an open, thin appearance with more dead twigs than normal. These symptoms are common to any trouble caused by an agency which kills roots or girdles the tree in whole or in part.

COMBATIVE MEASURES. To decrease the number of cases of dry root rot, avoid excessive watering; do not permit water to stand in contact with tree crown. The precautions suggested to combat brown rot gummosis in young trees apply here also. Gummosis lesions will favor the early development of dry root rot.

Treatment may be applied in the early stages. Cut into the affected roots and remove the diseased bark and wood to ¼ or ½ inch beyond the margins of the affected parts. Then disinfect with

2 per cent mercuric cyanide or mercuric chloride in 25 per cent denatured alcohol in water. Allow to dry thoroughly, then cover with thick asphalt paint.

Girdled roots, or those that are extensively damaged, should be cut out and removed. The cut should be disinfected and covered, as above.

In advanced stages, nothing can be done. The tree should be removed.

Rio Grande

Gummosis

Rio Grande gummosis is the more common name for a disease that Godfrey (20, 21, 22) has called "infectious wood necrosis and gummosis" and which is considered one of the most serious citrus tree diseases in the southern Texas area. So far, in California the disease or a similar malady called "ferment gum disease" has affected only grapefruit trees.

Not all the factors involved in the cause of Rio Grande gummosis are known although certain microorganisms isolated from infected wood have reproduced some of the symptoms when inoculated into trunks and large limbs (7, 12).

SYMPTOMS. The disease apparently starts at injuries and pruning wounds.

At the place of entrance and where the advancing band of infection grows out

Left: Rio Grande gummosis (ferment gum disease). Right: Artificial reproduction of the disease (from unpublished work of E. C. Calavan and J. M. Wallace). Photos by T. A. DeWolfe.

to the wood surface and kills the cambium, the bark cracks and gum exudes profusely. (See photo, page 12.)

The affected wood, which is dusky in color, with a narrow orange-colored margin, occurs in a band often an inch or more below the surface, so that it is necessary to chisel through unaffected wood to discover the stained tissue. The band of diseased wood ranges from ¼ to 2 inches in thickness, may be several inches wide, and may spread upward and downward 2 or more feet from the point of infection.

Avoid Rio Grande gummosis by disinfecting and coating all pruning wounds and injuries made by ladders—the most likely places for infection to start.

CONTROL MEASURES recommended include pruning off severely affected branches and, where feasible, chiseling out affected wood in the trunk and larger limbs. According to Godfrey healthy, exposed wood resulting from this pruning and/or chiseling should be treated with a penetrating disinfectant, such as carbolineum, with 2 per cent phenol. He states that final coating on the excavations should be made with a material consisting of equal quantities of low melting point asphalt and carbolineum with 2 per cent phenol.

However, disinfection with 2 per cent mercuric cyanide, or 2 per cent mercuric chloride in 25 per cent denatured alcohol in water and (when dry) covering with asphalt paint, as in treatment of wood infections by *Diplodia* or *Dothiorella*, should be satisfactory.

In either case, if the disinfected wounds are not covered, there is danger that secondary, wood-destroying fungi will invade the affected areas and cause more trouble.

Psorosis

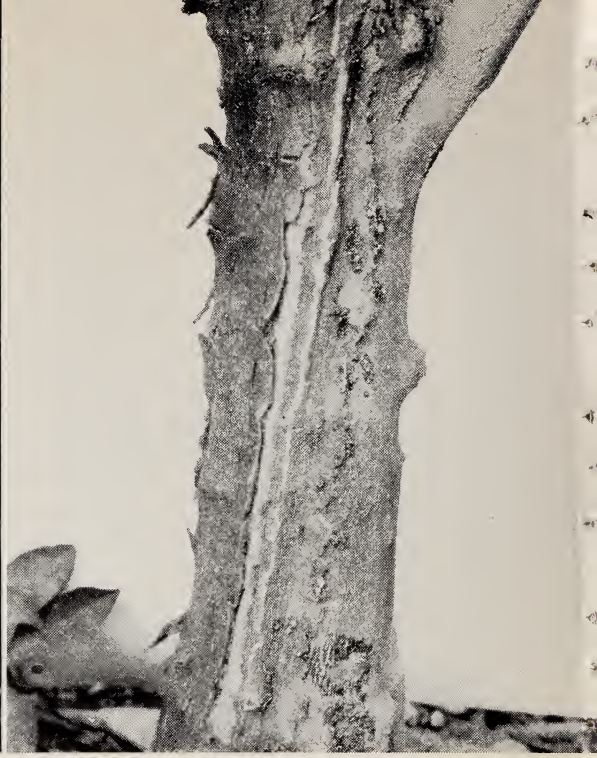
or Scaly Bark Diseases

The general symptoms. The following virus diseases of citrus are discussed under the general heading of "Psorosis Diseases" because, while having distinguishing symptoms, all have a common or general leaf symptom on young leaves. This symptom appears as numerous small, elongated clearings or flecks, from light green to yellow in color, lying along the small veinlets. They vary in size from .04 to .12 inch in length and .02 to .04 inch in breadth. They may occupy the entire surface of the leaf blade or only small areas. Sometimes the flecks form a pattern similar to a watermark outline or oak leaf outline. (See photos, page 14.)

These marks may be most readily seen by viewing them in the shade, with the light from the sky coming through the leaf. In choosing leaves to examine, make sure that they are free from injury due to sand blast, hail, red spiders, thrips, leaf hopper punctures, etc., which might be mistaken for psorosis symptoms.

The symptoms of psorosis in leaves are frequently evident long before bark, wood, or fruit symptoms appear.

Cause. From the universal leaf symptoms and from other relationships explained below, it appears that all psorosis diseases are caused by related strains of virus. They induce one or more distinguishing symptoms on bark or leaves or fruit. At least two strains, psorosis A and crinkly leaf psorosis on sweet orange, grapefruit, and mandarin, cause bark lesions and have come to be known in California as scaly bark. Inasmuch



Left: Typical scaling bark lesions of psorosis A which develop spontaneously on trees propagated from diseased parent trees. Right: Extensive development of a rampant form of psorosis A which resulted from experimental inoculation of a healthy tree with bark from a local psorosis A lesion. This form rarely occurs naturally.

Left: Orange leaves with the typical flecking pattern denoting infection by psorosis A. Center: Oak leaf pattern of clearing associated with concave gum psorosis (photo by J. M. Wallace). Right: Target shaped markings on orange leaves associated with the rampant type of psorosis A.

Left to right: The typical symptoms of concave gum, blind pocket, and eruptive blind pocket types of psorosis. These diseases are most commonly found in orange trees. There is no effective known treatment for any of these troubles.

Left: Grapefruit leaves with the small, necrotic ring markings associated with the rampant form of psorosis A. Right: These are the typical misshapen fruit and leaf symptoms associated with infectious variegation.

as the Leprosis disease on Florida citrus is also called scaly bark in that state, it is advisable to avoid confusion by adopting the name psorosis for the diseases here described.

None of the psorosis infections can be cured permanently by present known methods. All of the diseases cause a gradual deterioration of the trees until they are commercially useless.

Steps can be taken, however, to avoid psorosis, and certain measures have been found that will prolong the useful lives of trees having psorosis A.

THE SPECIFIC SYMPTOMS that will usually determine what type of psorosis infection has taken place are as follows:

Psorosis A brings about scaling bark lesions on sweet orange, grapefruit, and tangerines, and stunting of some trees, notably lemon. (See photos, pages 14 and 15.)

This disease usually appears first on the older bark of the trunk or limbs of trees 12 or more years old and seldom on trees younger than 5 years. It is evidenced by small scales with or without gum formation, or as groups of pustules (blisters) under which are brown specks. The scales from the outer layers of bark are dry, irregular in shape and about 0.1 of an inch thick. The bark underneath them is living, and is tan to buff in color.

As the disease advances, the deeper layers of bark and wood become affected. The wood layers become infiltrated with gum and resinlike materials, and later become stained a reddish brown. Such wood loses most of its function of conducting soil solution and the tree then deteriorates rapidly, showing sparse foliage and many dead twigs.

A severe and rampant form of *Psorosis A* is occasionally seen. It can be distinguished from the local, slowly-spreading type by the fact that gumming appears first and precedes the scaling. Experimentally Wallace (27) produced it by grafting a trunk or branch of a healthy tree with a bark patch taken at the edge of a psorosis lesion. This type advances very rapidly in continuous strips of gumming and scaling areas on the trunk and larger branches. Small branches and twigs are affected in the early development of the disease. In addition to the general leaf flecking some leaves and fruit may show necrotic ring spots of varying sizes. Types of psorosis A intermediate between this and the common types have been observed.

Concave gum psorosis is found on orange trees. (See photo, page 15.) On the trunk and limbs it produces relatively broad concavities—a result of the virus' retarding and at times arresting the formation and growth of wood in the affected parts. Bark covering these depressions is apparently normal, but may sometimes crack open and allow gum to ooze to the surface. Tissue on the surface layers of wood is gummy or granulated and reddish brown in color.

The underlying layers of wood are usually thinner than normal for the season's growth, and are impregnated with a substance semiliquid to semisolid or cheesy or gummy in consistency.

While the affected layers of wood are thin and filled with gum, some layers that appear normal in thickness and color may be found in the concavity. Young leaves regularly show the oakleaf pattern of clearings.

Blind pocket psorosis of orange causes an abruptly narrow creasing in the surface of the trunk and limbs, giving a fluted effect (see photo, page 15). Some cases have less abrupt slopes and resemble those of concave gum disease.

The concavities vary in size from a few inches to the entire length of the trunk.

Tissue in the wood at the bottom of the crease is softer and less dense than normal, and is yellow to yellow-salmon in color. Eventually it is impregnated with a waxy or gummy material.

Occasionally blind pocket disease will be accompanied by exudation of gum from the pockets, and by the formation

of scales that are coarser and thicker than those found in psorosis A.

Crinkly leaf psorosis disease of lemons causes no apparent injury to the bark or wood of the lemon tree. The only symptoms of the disease are the flecking of the young leaves and a warping and pocketing of the leaves and distortion of the fruit on some branches (see photo, page 15).

Infectious variegation has all of the symptoms of crinkly leaf (see above) and in addition, a leaf variegation caused by an irregular chlorosis (discoloration) of the leaf blade. Lemon fruits may be deformed and have dead areas in the rind. Sweet orange seedlings budded with buds from lemon trees having crinkly leaf or infectious variegation develop the typical bark scaling of psorosis A, indicating the relationship of the diseases. It causes distortion and variegation of sour orange leaves. This psorosis type is not frequently seen in the orchard (18).

COMBATIVE MEASURES. While psorosis can not be cured, it can be avoided by using buds only from trees that are known to be free of symptoms. Since the only known means of transmission of the psorosis diseases is by union of living tissue (budding and grafting) or by an occasional natural root grafting, there is no significant spread from tree to tree. The Nursery Service of the California State Department of Agriculture, for a small fee, supplies an inspection service to assist growers and nurserymen to secure citrus budwood free of the scaly bark virus.

Treatment can be given to prolong the useful life of a tree that has become infected with scaly bark, as listed below:

***Psorosis* bark lesions** should be treated in the early stages, when the lesions do not exceed the area of a man's hand.

One treatment consists of scraping the outer layers of bark over the affected part and also over the apparently healthy bark for a distance of 6 inches above and below, and 4 inches to sides around the lesions. Scrape to a depth sufficient to remove the discolored layers (¼ to ⅓ the thickness of the bark). See Fawcett (14, 15, 16), and Klotz and Fawcett (24).

No disinfectant is needed after scraping if the treatments are made in the late spring and summer months when the bark recovers most rapidly. Bark scraped in the late fall or winter is subject to injury by low temperatures.

Another treatment, that enables one to do the work of several workmen scraping, has been developed.

In this treatment the loose scales are removed with a bark scraper or by rubbing with a gloved hand or fiber brush. The affected area and the unaffected bark as in the scraping treatment are then painted with a solution of 1 per cent dinitro-o-cyclohexylphenol (dinitro) in kerosene (DN 75). See Fawcett and Cochran (17), and Rounds (26).

Great care is necessary in applying this solution to avoid subsequent injury or killing of the bark through to the wood. Use a small, thin brush with bristle portion measuring about 1½ inches in width and 1¼ to 1½ inches in length, and about ¼ inch thick. The brush is dipped into the solution and then pressed against the side of the container to remove excess liquid so that when it is applied to the bark surface, the liquid will not run, but will be just sufficient to cover the area. Do not go over the area a second time. Excessive amounts applied accidentally should be wiped off with a cloth.

The best time for the dinitro treatment depends on the weather and tree conditions. Recent tests show, however, that if properly applied, this material can be used effectively during any month of the year.

Wet periods should be avoided. The material should not be applied to wet bark or just before a rain because the kerosene does not volatilize rapidly under these conditions and may penetrate too

These are before and after pictures of a psorosis A infection that was treated with dinitro. This treatment, described on page 17, must be given with great care to avoid damage from kerosene.

deeply. Where the kerosene evaporates rapidly little injury can result unless too much solution has been applied. On small limbs, even when the chemical is carefully applied, parts of the lesion bark may be killed, but this damage will be less than would result from leaving the lesions untreated. Previously scraped lesions have a thin, porous bark which is readily injured by DN 75. These areas should be given only a light application of the solution.

The dinitro treatment can be applied at a cost of approximately 25 cents per tree, including labor and materials. It should be emphasized here that these treatments do not cure a tree, but merely retard lesion activity. To prolong the useful life of the diseased tree it is necessary to repeat the treatment at intervals, including any new lesions that develop.

The rampant form of psorosis A, concave gum, and blind pocket psorosis diseases cannot be treated economically by surgery or any other known method. When trees decline to the point where they are commercially useless, remove them.

The same is true for trees showing symptoms of **crinkly leaf and infectious variegation** forms of psorosis.

Exocortis

(Bark Shelling) of Trifoliate Orange

This is an important virus disease (2, 4, 5, 6, 13, 19, 28) among orange trees on rootstocks of trifoliate orange or on hybrids of this stock. Some orchards of old trees have shown from 5 to 25 per cent infection with a retarded growth (stunting) of the affected trees.

THE BARK SYMPTOMS resemble more nearly those of shell bark of lemon than those of scaly bark of orange and often appear at or below the soil surface. Narrow strips of the outer bark dry and separate from the inner live bark and slowly peel off as they weather. This is similar to the peeling of a shell bark hickory tree (see photo, at right).

The bark strips are 1 to 5 inches long, $\frac{1}{8}$ to 1 inch wide and $\frac{1}{10}$ to $\frac{1}{8}$ inch thick. On the surface of the bark beneath the shelling bark a layer of hardened gum sometimes forms. Because of the general association and similarities of symptoms, Calavan and Weathers (10) "suggest that exocortis virus may possibly be an important causal factor in the development of shell bark on many lemon trees."

While trees on healthy trifoliate orange are generally smaller than the same varieties on some other commercial rootstocks, the stunting is much more marked when the trifoliate stock shows shelling. The trunk diameter of two 23-year-old navel trees on shelling trifoliate in an experimental planting measures only half that of 20 other trees on unaffected trifoliate stocks. The volumes of the tops of the diseased trees were only $\frac{1}{6}$ to $\frac{1}{5}$ of those of the healthy trees. However, some investigators feel that much or all reduction in growth is caused by a factor or factors other than the virus of exocortis.

COMBATIVE MEASURES. Bark shelling cannot be cured but, assuming the absence of an insect vector, it is possible to avoid the disease by taking the following precautions:

1. Avoid using budwood from trees on trifoliate which show evidence of the trouble. While there is no evidence at present that the disease is transmitted through seed, as a matter of precaution seed from affected trees should be avoided.

2. The safest measure is to take budwood from trees that have grown on non-dwarfing, non-shelling trifoliate stock for at least 10 years. Moreira* tests for the

* Information by letter dated 3 February 1960 from Professor Sylvio Moreira, Campinas, Brazil.

This is a closeup of a trifoliate orange rootstock, showing typical symptoms of bark shelling. This disease also results in stunting of trees.

presence of exocortis virus by budding 1 to 2 year old seedlings of Rangpur lime with buds from the prospective budwood tree and, after the bud "takes," cutting back the tops at 5 cm above the budding point. The 2 or 3 vigorous sprouts growing from the Rangpur lime butt will show yellow streaks and splitting of the bark within 4 to 5 months if the bud is from a tree having the virus. By growing buds of candidate trees on trifoliate stock in sand with a high concentration of nitrogenous fertilizer (1,000 ppm or more of N) Weathers (28) obtained shelling symptoms in approximately 10 months. The interesting chemical tests of Childs, Norman, and Eichhorn (13) while still regarded as presumptive by the authors, are useful as confirmatory tests and as indicators early in the development of the disease.

Minor Forms

of Gumming

Several fungi, including *Penicillium roseum*, which in coastal sections has at times been found associated with Botrytis gummosis and shell bark; *Fusarium* spp. which is often associated with brown rot gummosis; *Alternaria* spp.; and some of the wood-rotting fungi, as *Schizophyllum commune*, are capable of inducing the formation of small amounts of gum. The amount of bark injured or killed by these fungi is very small.

Grasshoppers, katydids, fire ants, and probably other insects (11) feeding on the bark, cause a formation of gum at injuries. Fire ants are controlled by spraying with 4 pounds of wettable chlordane (50 per cent active) in 100 gallons of water. Red scale may induce profuse gumming by their feeding and injection of toxic materials.

Injury accompanied by gumming on trunks can be caused by spilling of liquid hydrocyanic acid on the soil, or by applying the gas under unfavorable conditions, such as:

1. Too soon after irrigation.
2. When temperatures are above 70° F.
3. During cold weather, when dew has formed.
4. In sunlight.
5. Following copper sprays. See Klotz and Lindgren (25).

Typical symptoms of gumming caused by HCN fumigation injury. This type of injury may follow fumigation when conditions are not right. (Photo by J. T. Barrett.)

Unneutralized copper sulfate or arsenicals contacting a root or trunk bark will kill bark in vertical strips and induce gum formations. Strong concentrations of 2,4-D (9) other weed killers and fertilizers can induce gumming, when brought into contact with bark of trunk or roots.

Copper deficiency causes a nutritional disease called exanthema, in which gum formation is a prominent symptom. Gum collects at or near the leaf nodes of young succulent branches, and at the angles of fruit segments. Surfaces of twigs, leaves, and fruit become infiltrated with a brown, hard gum.

The trouble is corrected by spraying the entire tree thoroughly with 1-1-100 bordeaux mixture, or with 5-1-4-100 zinc sulfate-copper sulfate-hydrated lime. Spraying may be done just before the spring flush of growth, or at any convenient time during the year.

Mechanical injuries do not induce gumming by themselves, but as stated, they do open the way for infection by various fungi. Injuries from sunburning and freezing almost always become invaded by fungi.

Acknowledgments

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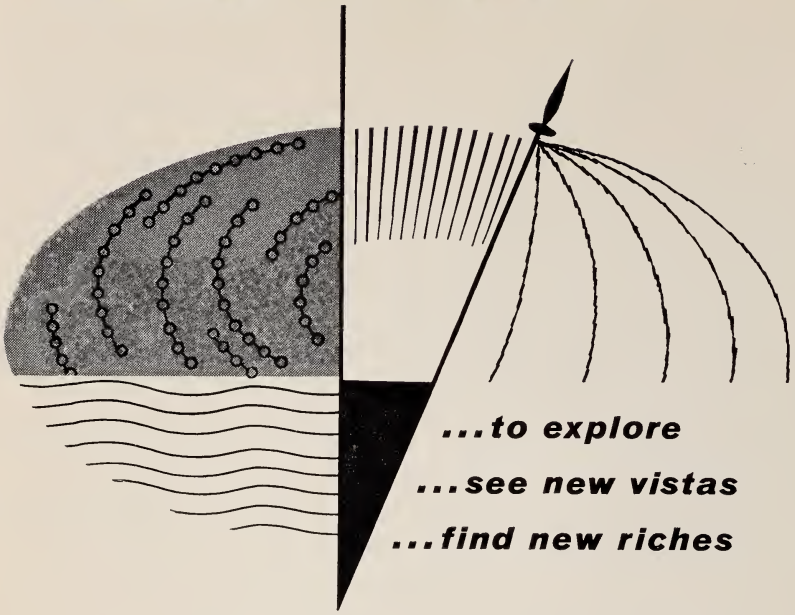
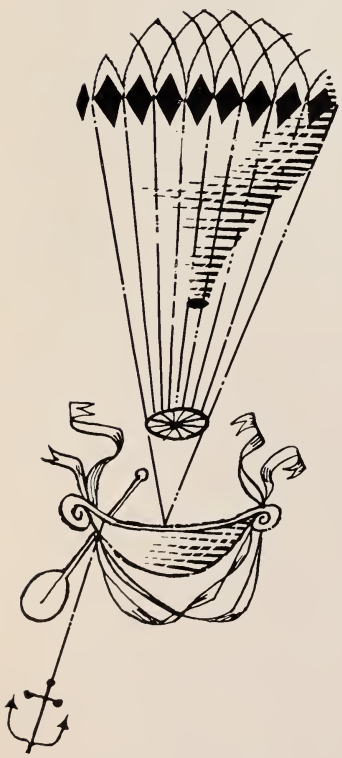
PURPOSES OF A UNIVERSITY...





"I like to compare scientific research
to mountain climbing in an unexplored range.
Considerable preparation, training, and a strong
motivation are required to get up to the
upper altitudes even if no one particular stretch
of the way is particularly difficult.
But once there, it is relatively easy for one
to see vistas or even to stumble across
new riches that people of equivalent ability
who have stayed behind, have no
possibility to see or to find."

GLENN T. SEABORG
Nobel Laureate in Chemistry, 1951

(From his address at the Secondary Education Board Conference, San Francisco, April 5, 1957)